# Lead Corrosion: What Research is Needed?

## Or:

## *"Aren't we done yet?"– The regulators' lament…*

**Michael R. Schock**
Water Supply and Water Resources Division
Office of Research and Development
U. S. Environmental Protection Agency
Cincinnati, Ohio

# Lead and Copper Rule: US

- First proposed: 1988
- Covers all public water supplies and non-transient non-community supplies
  - 75,000+ total public water systems
  - 680+ over 50,000 population
  - Administered at State level for 49 of 50
- Substantially revised and promulgated: 1991

# Regulatory Approach

- "Treatment Technique" rather than hard MCL for large systems
- Sampling scheme intentionally biased for site selection

# Regulatory Approach

- "Action Level" is trigger
  - Optimization of corrosion control (large)
  - Corrosion control studies and treatment to meet 0.015 mg/L for others
  - Public education
  - Possible service line replacement
- Must meet other SDWA regulations at same time

# Origin of Continued Problems

- US regulations primarily organized by “contaminant”
- Pre-regulatory research not always completely comprehensive or accurate
- Pre-regulatory research timeframe and resources often too limited
- New regulations come into affect that interact.
- So… Public water systems get to figure the rest out!

# Implementation Discoveries

1. **Unexpected behavior after "corrosion control"**
   - **Different physical nature of plumbing or distribution systems than covered by research or that are amenable to the treatments**
   - **Different water chemistry conditions produce serious corrosion problems, e.g. Pb/Cu differences**

- **Thus, deficiencies in knowledge of lead corrosion are learned the "hard way!"**

# Implementation Discoveries

2. **PWS wish to make subsequent water quality changes**
   - **Changes in treatment caused by new regs**
   - **New water sources**
   - **Adverse secondary impacts**
   - **More stringent sludge/wastewater limits**

- **New questions arise to anticipate adverse health effects or water quality impacts**

# Implementation Discoveries

3. **Lag time of years may be needed for chemical reactions to take place**
   - **Water quality impacts (good or bad)**
   - **Hydraulics**

- **Utilities may only now be seeing effects of treatments started years ago!**

# Objectives and Origins

- Based on both published and unpublished reports
- Questions involving
  - Significant data gaps
  - Reliable information lacking sufficient detail
- Spur new research initiatives

# Major Topics

- Solder and Copper Alloy Corrosion
- Lead Service Lines and Premise Plumbing
- General Lead Chemistry and Toxicity
- The Regulatory Balancing Act

# Lead Solders and Copper Alloys

- To what extent is control of lead release from brass fixtures and joints possible using only central water treatment?
  - 1-L first draw approx. 20-25 ft (6-8 m)
  - Turbulent & erratic environment
  - Any clear preferred strategy (e.g. pH vs. ortho-P)?

# Lead Solders and Copper Alloys

- **Corollary Questions:**
  - **Are there optimizations that differ from those best for Pb pipe?**
  - **Will the problem go away with selective leaching, reduced Pb or reduced surface exposure?**
  - **Does the timeframe differ with different waters?**

# Lead Solders and Copper Alloys

- Do cathodic inhibitors play a significant role in limiting or mitigating lead release from these sources?

# Service Lines and Premise Plumbing

- Partial lead service line replacement
  - Elevated Pb levels?
  - How high? How long?
  - Relation to scale composition and/or water chemistry?
  - Can certain treatment strategies mitigate better?

# Service Lines and Premise Plumbing

- To what extent are lead pipes covered with diffusion barriers or protective deposits composed of non-Pb solids?
  - Al compounds
  - Mg silicates
  - Calcium and other carbonates or phosphates
- How stable are these deposits in response to specific treatment changes?

# Service Lines and Premise Plumbing

- **Corollary questions:**
  - **What are main elements or functional groups?**
  - **To which water quality or treatment processes do they relate?**
  - **What is the optimum DIC/pH combination to produce most robust film in shortest time?**
  - **If barrier films are unstable in new water chemistry, how long will it take for**

# Service Lines and Premise Plumbing

- Do the solubilities of basic lead carbonates and lead carbonate decrease with age?
  - Possible analogy to copper solids where metastability dominates
  - Would improve understanding and predictability of extrapolation from pilot scale or bench to field

# Service Lines and Premise Plumbing

- Are there other significant solubility-controlling solids under certain water conditions (especially at lower pH's)?
  - $PbSO_4$ [anglesite]
  - $Pb_4SO_4(CO_3)$ [leadhillite/susannite/macphersonite]
  - $PbO \cdot PbSO_4$
  - Others?

# Service Lines and Premise Plumbing

- How well can the best combination of startup inhibitor dosage and maintenance dosage be predicted?
- What is the best startup approach for phosphate inhibitor dosage?
  - High, then decrease
  - Slowly increase

# General Lead Chemistry and Toxicity

- When, if ever, are blended phosphates superior for controlling lead release?
- Can the impact of source water NOM on lead release be predicted?
  - Most research results explain after the fact
  - Necessary to predict impact of D/DBP control strategies and simultaneous compliance

What is best choice for predictive model

# General Lead Chemistry and Toxicity

- What are precise dosage/pH interrelationships for orthophosphate dosing across a wide range of water qualities?
- How does the net lead solubility and reactivity of active inhibitor component vary with temperature or other “seasonal” factors?

# General Lead Chemistry and Toxicity

- Does the speciation of the lead resulting from different lead control strategies produce possibly different degrees of human bioavailability?

# The Regulatory Balancing Act

- Can changes in coagulation type (e.g. alum to ferric chloride, or PACl) affect lead levels?
  - Mechanism?
    - Scale solubility?
    - Destabilization by charge differences?

# The Regulatory Balancing Act

- What is the point of practical tradeoff between pH stability (buffer intensity) and possible increases in plumbosolvency or Pb release through added carbonate complexation?

# The Regulatory Balancing Act

- To what extent does orthophosphate or polyphosphate(s) interact with residual aluminum?
  - Reduction of effectiveness of ortho-P for Pb or Cu control?
  - Formation of Al deposit reducing release
  - Adverse effect on hydraulics and aesthetics

# The Regulatory Balancing Act

- **Corollary questions:**
  - **Does a solid material form?**
  - **Does the material have detrimental hydraulics effects?**
  - **Which species are involved?**
  - **Can the films be removed without detrimental effects on Pb or Cu?**
  - **If Al-based, does type of coagulant matter?**

# The Regulatory Balancing Act

- Are the products of chlorination or “advanced” oxidation of NOM more or less detrimental to lead release than “naturally-occurring” NOM species?
  - Is $O_3$ without BAF detrimental?
  - Does the effect vary if pH/DIC is used as opposed to phosphate dosing for control

# The Regulatory Balancing Act
## Fe/Mn interactions

- Do high redox potentials caused by high DO levels (post $O_3$) or Fe/Mn oxidation favor rapid passivation by $PbO_2$?
- What are the relative advantages and disadvantages of oxidation and physical removal vs. sequestration for different waters

# The Regulatory Balancing Act

- What are the impacts of different types of phosphates on the passivation and lime leaching from cement pipes and linings?
  - Phosphate chemical species effects
  - Background water chemistry effects?

# The Regulatory Balancing Act

- How important is overall Pb/Cu control optimization to levels beyond drinking water requirements to satisfy wastewater discharge and sludge limits?
- Is more wastewater process research needed to optimize P, Zn, Cu, etc. removal?
- What are the impacts of different treatment approaches on hot water

# Conclusions

- Considerable progress in 10 years, but
  - Some old questions remain
  - New questions evolve out of other needs
- Bad timing for research funding when in implementation stage
- Lead control by central water treatment must be integrated into holistic scheme

# The Keys are in the Scales

- Reflects past treatment and likely response to future changes
  - Mineralogy
  - Surface chemistry
- Overall, very few pipes have been studied
- Need to integrate knowledge of all distribution system materials, not just lead and copper